EVAPORATION MEMORANDUM NO. 30 **DUPLICATE** B G Wales-Smith

The evaporation component in the water balance of a refuse tip.

Potential evaporation.

From figures prepared by Grindley[1] the approximate average monthly proportions of annual total potential evapotranspiration for a typical location in lowland England are given below, together with monthly values in millimetres for an average annual total of 500 mm :

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	2	6	10	16	19	18	14	8	4	1	1	%
5	10	30	50	80	95	90	70	40	20	5	5	mm

The above figures are very close to the 1961-70 monthly averages from a British Standard evaporation tank at Kew Observatory, processed by the writer:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2	2	6	8	13	18	18	14	9	5	3	2	%
10	10	30	40	65	90	90	70	45	25	15	10	mm(for 500 mm total.)

The excess of tank evaporation above evapotranspiration in the colder months and of evapotranspiration above tank evaporation during the growing season is reasonable; the important point, in the present context, is the close similarity between the two sets of figures.

Measurements and calculated estimates of evaporative water loss from vegetation abundantly supplied with soil moisture (and thus able to transpire at the current maximum, or potential, rate) and from the surfaces of fresh water masses are made regularly at many places in the United Kingdom and elsewhere. Evaporation from bare soil and from other surfaces is not generally measured or estimated by calculation. Penman[2] discusses the difficulties in attempting to measure potential evaporation from bare soil and gives some values of the ratio of bare soil to open water evaporation at Rothamsted for periods in 1944 and 1945. A very rough average of his ratios is 0.8.

The writer is not aware of any experimental results of evaporation from the surface of a typical mass of saturated refuse. Assuming such refuse to contain a high proportion of highly absorbent material (e.g. paper, cardboard, vegetable matter, etc) and 70% has been suggested as a reasonable average based on available statistics, and assuming that the waste has not been pulverised (and therefore given a more or less flat top surface when on the tip)it seems probable that evaporation over an area of, say, 1 square metre would occur from more (perhaps much more) than that area of thoroughly wet material.

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Thus to measure the potential rate of evaporative water loss from a given surface it is necessary (a) to keep the material thoroughly moist, (b) to measure the water lost from the supply vessel and (c) to measure the rainfall, if any, falling on to the test surface. To calculate estimates of the potential rate of evaporative water loss from a surface it is necessary to have a ratio relating loss from this surface to that from open water or from a continuous cover of vegetation abundantly supplied with soil moisture.

Meteorological data required to calculate evapotranspiration/evaporation by the Penman formula.

As already remarked, monthly average totals of these two quantities are generally close for one location or for two similar locations with the same annual total. Either quantity may be estimated by making trivial adjustments to constants. For a given period of 5 days or more (see Wales-Smith[3]) good quality estimates may be obtained from averages of the following:

Daily duration of bright sunshine

Air temperature

Air vapour pressure

Wind speed at 2 metres above ground.

Instead of sunshine duration, incoming radiation data may be used; if net radiation data are available, estimates may be made for periods much shorter that 5 days.

Assessing the real rate of evaporation from a surface.

From open water and from vegetation and other matter freely supplied with moisture the real rate of evaporation is always the potential rate and it applies to the whole of the wet or transpiring area. Thus, as already mentioned, the water loss from a square metre of the earth's surface could occur from more than a square metre of some substance and hence the loss per square metre of the earth's surface would exceed the calculated or measured rate from water of from a continuous cover of vegetation not supporting intercepted or condensed water on most or all of its outer surfaces. At any rate, when there is no restriction on water availability, the simple potential rate of evaporation may be taken as the minimum rate if not the real rate.

Penman[4] and others have proposed models of the way in which real evapotranspiration falls below the potential rate when plants draw upon soil moisture reserves (in periods when potential evaporation exceeds rainfall) and soil moisture tension develops. To estimate the real rate of evaporation from an unsaturated area of typical refuse, with or without a cover of soil, ash, etc., it would be necessary to construct similar models from experimental results and/or from data already available. Given the potential rate of evaporation from the surface, the rainfall and a realistic "drying model" it should be possible to make good estimates of the real evaporative water loss.

Other methods of measuring real and potential evaporation.

Evaporimeters could be constructed using (a) a typical mass of refuse kept saturated and (b) a mass of refuse representative of the top layer of a tip. Both methods could be tried with a cover of soil, ash, etc.

Measurements of wind speed and humidity could be made at two or more levels above the refuse tip and the real vertical flux of moisture calculated. The sizes and response times of the wind and humidity sensors are critical and this method, although potentially powerful, has serious practical difficulties (see Taylor and Dyer[5]).

Heat generated by the tip.

Any heat generated in the tip and reaching its surface will enhance the potential and real rates of evaporation and the air temperatures used to calculate potential evaporation must, therefore, be taken over the tip.

Practical applications of measures of evaporation from refuse.

A main purpose of attempts to assess the water balance of a refuse tip is to establish the likely volume of effluent leaving the mass of waste material, to consider the seasonal variation thereof and the effluent volumes likely to result from the occurrence of extreme rainfall events. The variation of rainfall from monthly average is very much greater than that of potential evaporation. Rainfalls several times monthly averages occur with various frequencies (on average) and these frequencies can be estimated for any selected point or area in the U K by an objective technique set out in United Kingdom Flood Studies Report, Vol2, Meteorological Studies[6]. The Meteorological Office has a computer program to provide this service.

Special problems of refuse pits.

When a tip surface is substantially below the surrounding ground level it is most unlikely that the values of the meteorological variables used to calculate potential evaporation will be the same in the pit as over the surrounding countryside. Wind speeds in a pit are likely to be lower than outside, the bottom of the pit will receive less direct radiation than the ground at pit-edge level and, because the air cooled by evaporation will be moist and relatively heavy it will tend to remain over the tip surface thereby damping down the rate of evaporation. Using values suggested by Waggoner[7] for a "cool, moist, windy" climate, guesses can be made of plausible reductions in potential evaporation.

If the wind speed in a pit is reduced by 50 %, potential evaporation falls by 15%
If the radiation ,, ,, 20 % ,, ,, 10%
If the vapour pressure deficit ,, 20 % ,, ,, 10%

Thus the potential evaporation might be some 35% lower than outside the pit. On the other hand, heat generated by the tip might result in vertical air currents and enhance evaporation by providing additional energy. To make some allowance for this effect one might ignore the reduction associated with reduced vapour pressure deficit and adopt a 25% reduction in potential evaporation as a reasonable figure.

Example of a very rough calculation.

An average annual rainfall of 700 mm is assumed to occur in equal monthly totals which are assumed to be fairly evenly distributed in each month. Average annual potential evaporation at pit-edge level is assumed to be 500 mm, distributed as shown below. Potential evaporation at tip level is assumed to be 75% of that at pit-edge level. Percolation through the tip, emerging as effluent, is assumed to be a monthly, arbitrary percentage of positive values of (Rainfall minus Potential Evaporation). Due to an assumed, regular arrival of fresh, unsaturated loads of refuse it is assumed that the whole mass never reaches saturation (field capacity) and thus percolation is never allowed to reach the full value of (R - PE).

Month.	PE(mm)	.75PE(mm)	Rainfall (mm)	R - PE (mm)	Percolation %	Estimated perc. (mm)
Jan	7	5	59	54	80	43
Feb	10	7	59	52	80	42
Mar	30	23	58	35	50	17
Apr	45	34	58	24	20	5
May	70	53	58	5	0	0
Jun	90	67	58	-9	0	0
Jul	90	67	58	-9	0	0
Aug	70	53	58	5	0	0
Sep	45	34	58	24	20	5
Oct	25	19	58	39	50	20
Nov	10	7	59	52	80	42
Dec	8	6	59	53	80	42
Year	500	375	700			216

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